Forward neutron Asymmetries
-spin dependent and otherwise

Sebastian White
for the PHENIX and ATLAS collaborations

* 2 talks on new PHENIX and ATLAS results with Zero Degree Calorimeters(ZDC)
* review current understanding of forward n in Nucleus-Nucleus and pp
* my task is to present a lot of new material in a limited time

for ATLAS this is result of an intense 3 month push to complete detector (July 20 LHC technical stop) and produce calibrated data plots on:

- ATLAS ZDC L1 trigger cross sections
- VdM based luminosity calibration
- Energy scale
- reconstructed di-photon mass distribution
- high resolution TOF (today <100 picosec !)

still in ATLAS blessing process:

- full simulation in ATLAS and LHC beamline of PYTHIA6 and RAPGAP diffractive and non-diffractive trigger cross sections.

pp collider forward physics- then and now

- new very forward data from LHC dominated today by LHCf (completed) and the ZDC(s)
- leading proton@Tevatron has been very productive
- accelerator optics used as excellent spectrometer but miniscule coverage: $1-x_F<.05$

in Heavy Ion world (NN and e-N) leading proton method hasn't been applicable

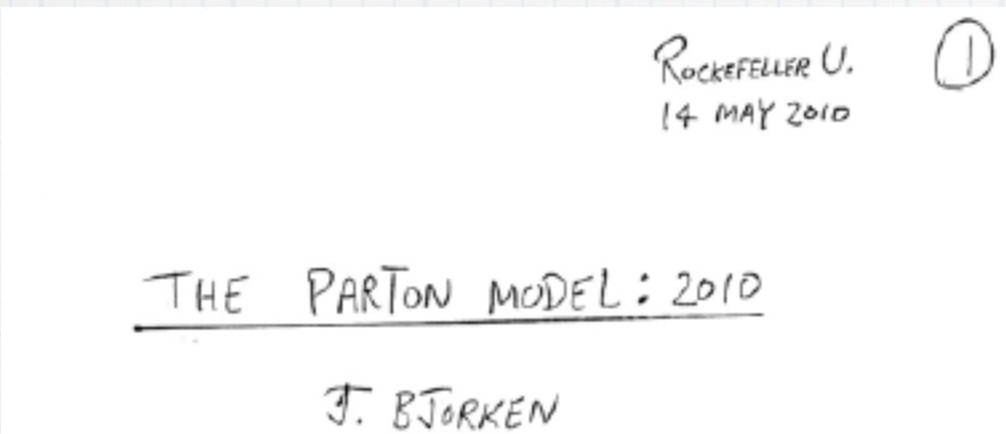
* Rigidity scale differs from beam by A/Z-1
* forward neutron has been dominant.
* in http://arxiv.org/pdf/1003.2196 M.Strikman &SNW showed n,gamma is key to much of e-Nucleus collider physics
* as in pp diffractive program, forward n physics in HI dominated by x_F\sim 1.

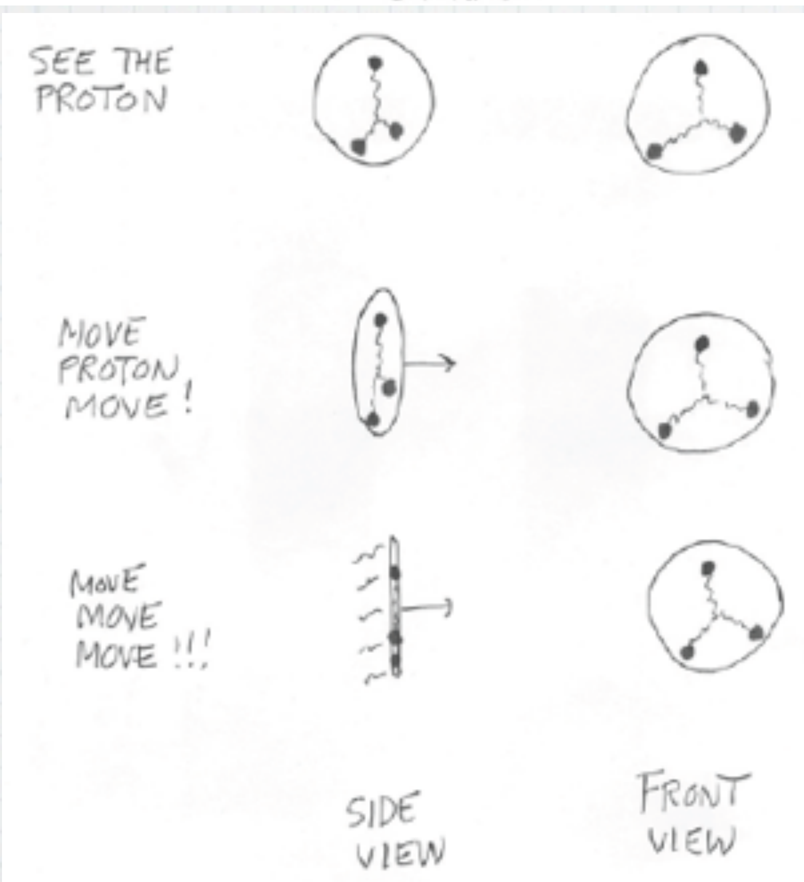
what is new?

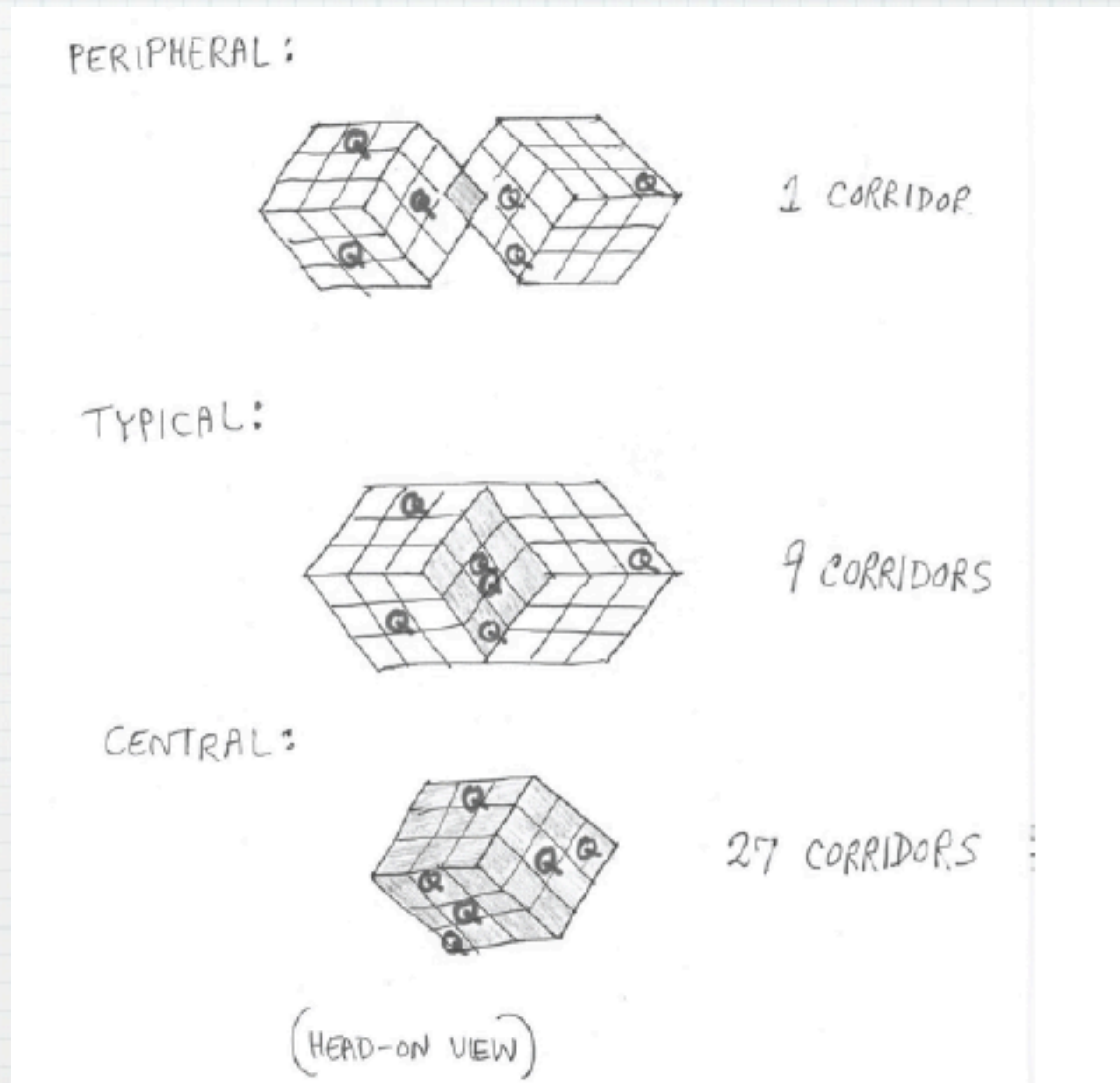
- with ZDC in ATLAS (& PHENIX) access new aspect of pp collider physics
  - forward baryons w. $0.2<x_F<1.0$
  - 45% of time there is a forward neutron
  - characterize pp collisions as done w. HI

* Shrinking diffractive peak in pp
* and increasing hard component @ LHC

-> characterize pp collision geometry(Bj)







Cross sections (a bit of Italian History)

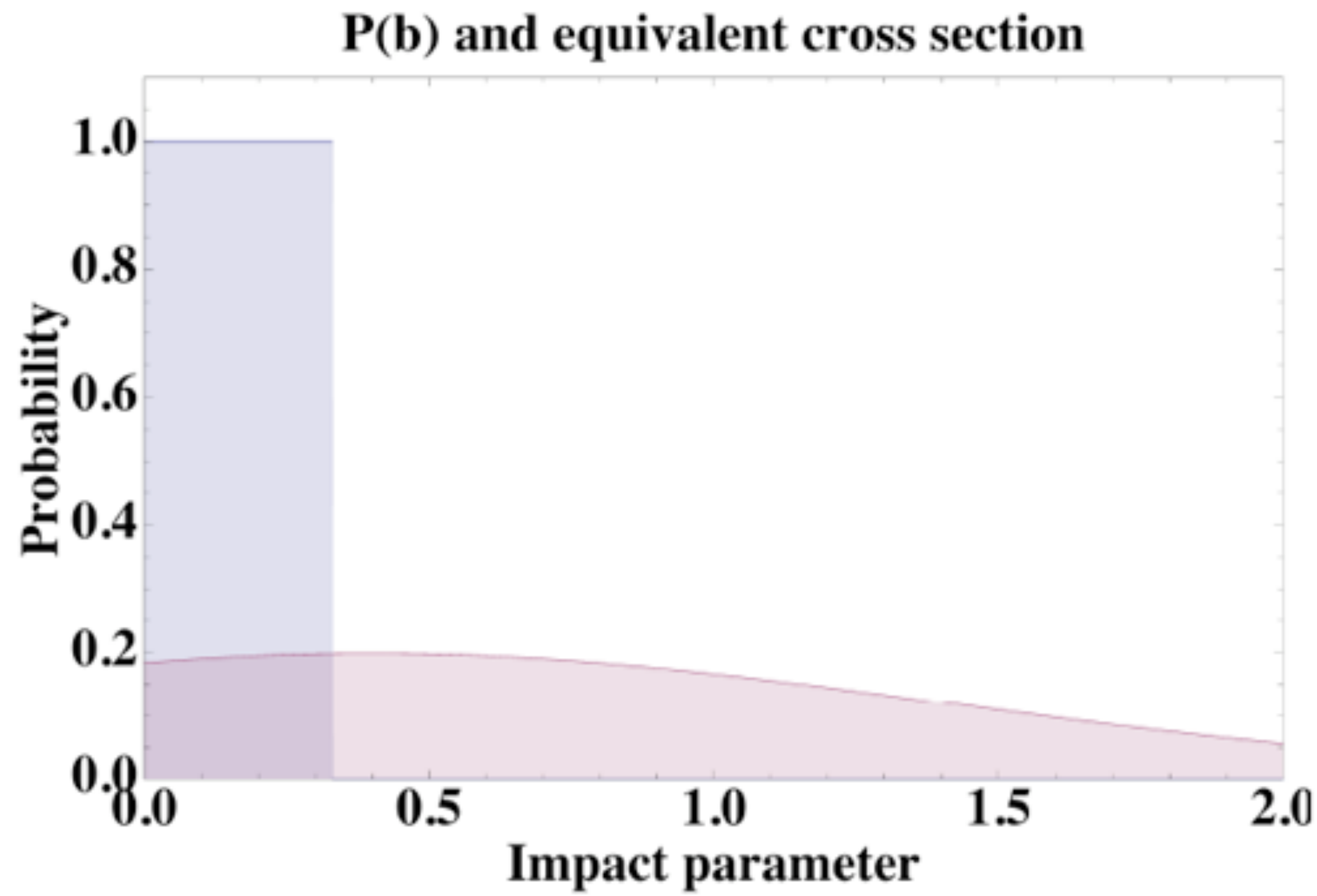
Equivalent field of light is calculated for each impact parameter.

But Impact parameter unmeasurable (i.e. ~10^{-10} meters)

->calculate an equivalent radius

$$\pi\rho^2 = 2\pi\int b \times P(b) \times db = \sigma$$

-> cross section (σ)



Units:

1 barn= 10^{-24} cm^2

1barn/atom->~1 interaction for typical target

Examples:

Gold+Gold->e^+e^-+Gold+Gold = 33,000 barns

Proton-proton Interaction ~0.1 barns

Diffractive Higgs@LHC =10^{-14} barn

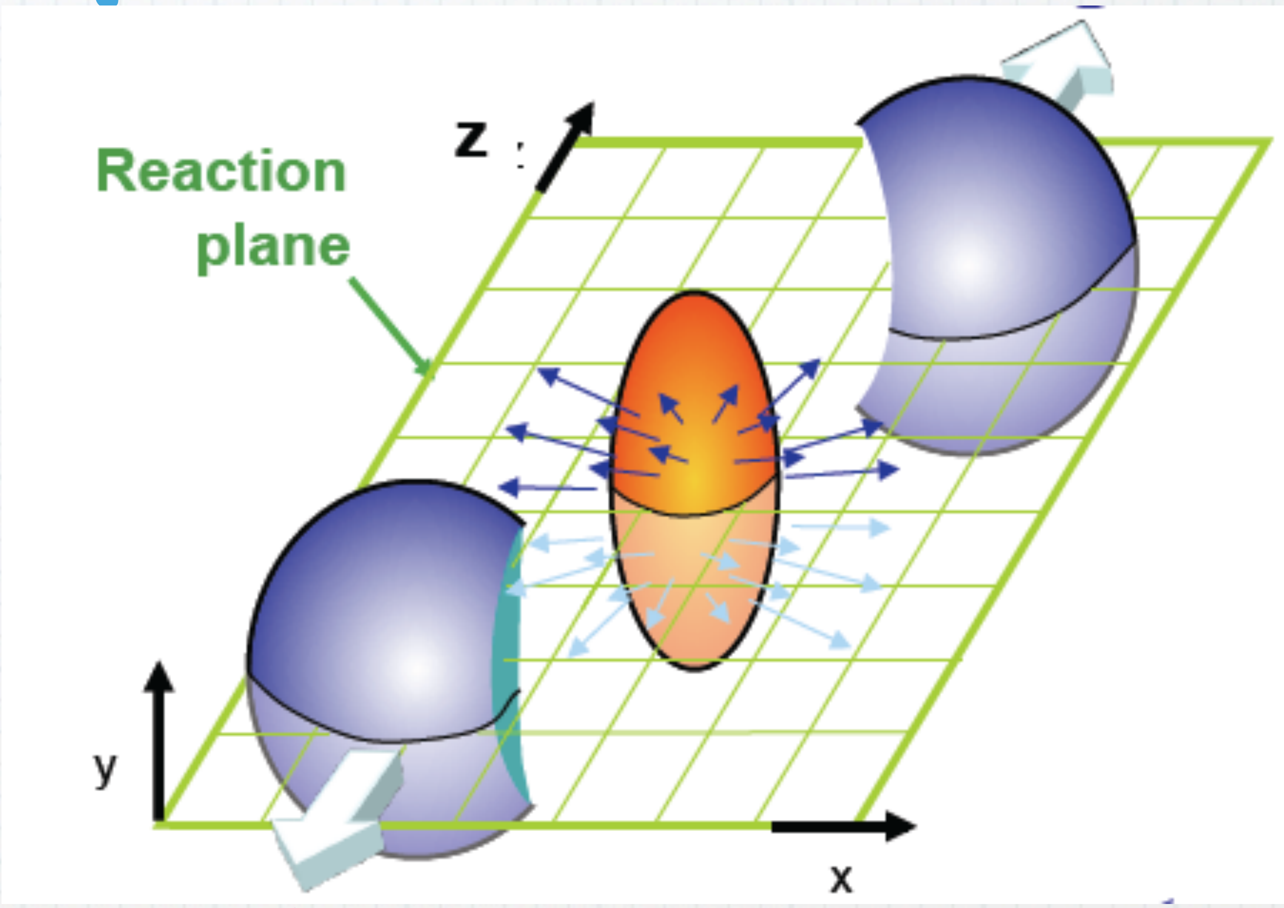
* in this community (see eg. Frankfurt, Strikman& Weiss, in preparation) ATLAS data presented by E.Nurse show that collisions with parton p_T from 2->few 100 GeV produced in a range w. small b, which is weakly varying over this range
* comparisons to b modeling in PYTHIA
* Gluon density in "central" LHC pp as large as in RHIC AuAu collisions (Frankfurt et al)
* ZDC is about event characterization

what do we know about forward neutron production? 1) Heavy Ions

Standard Picture ->

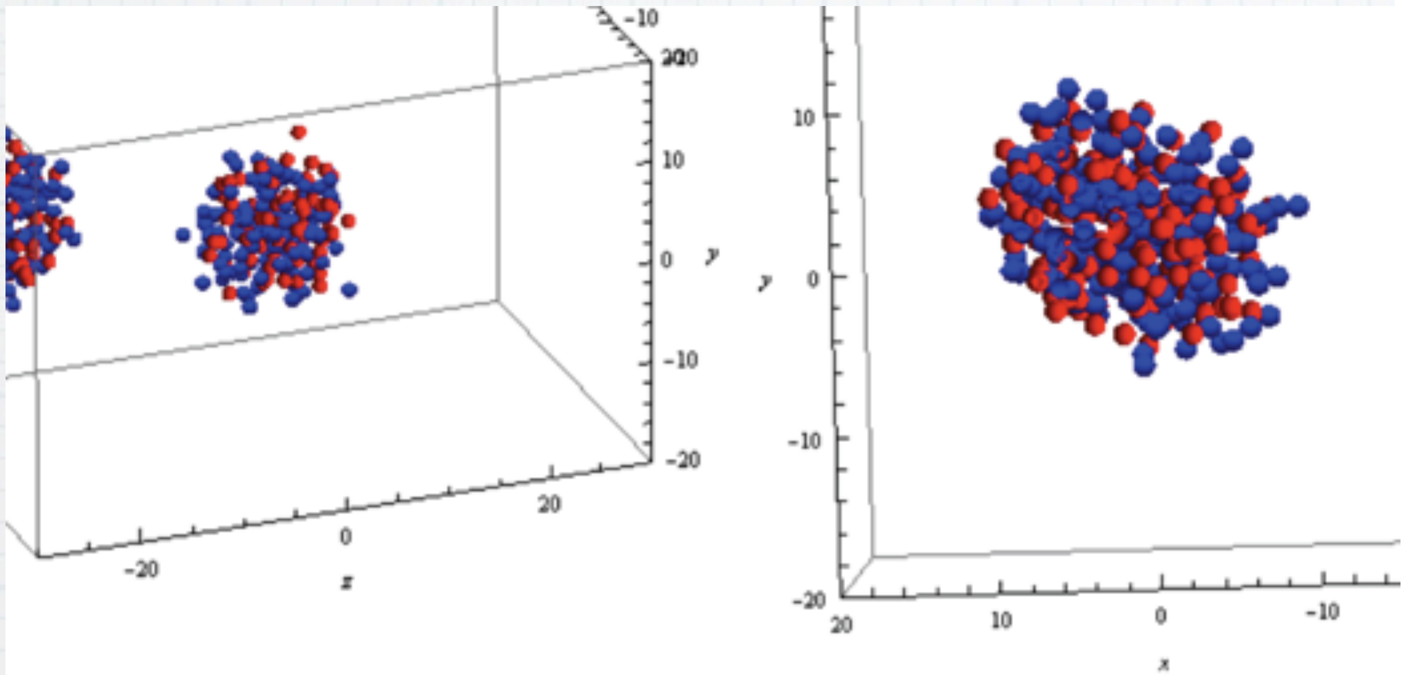
(Masashi Kaneta/Shinichi Esumi)

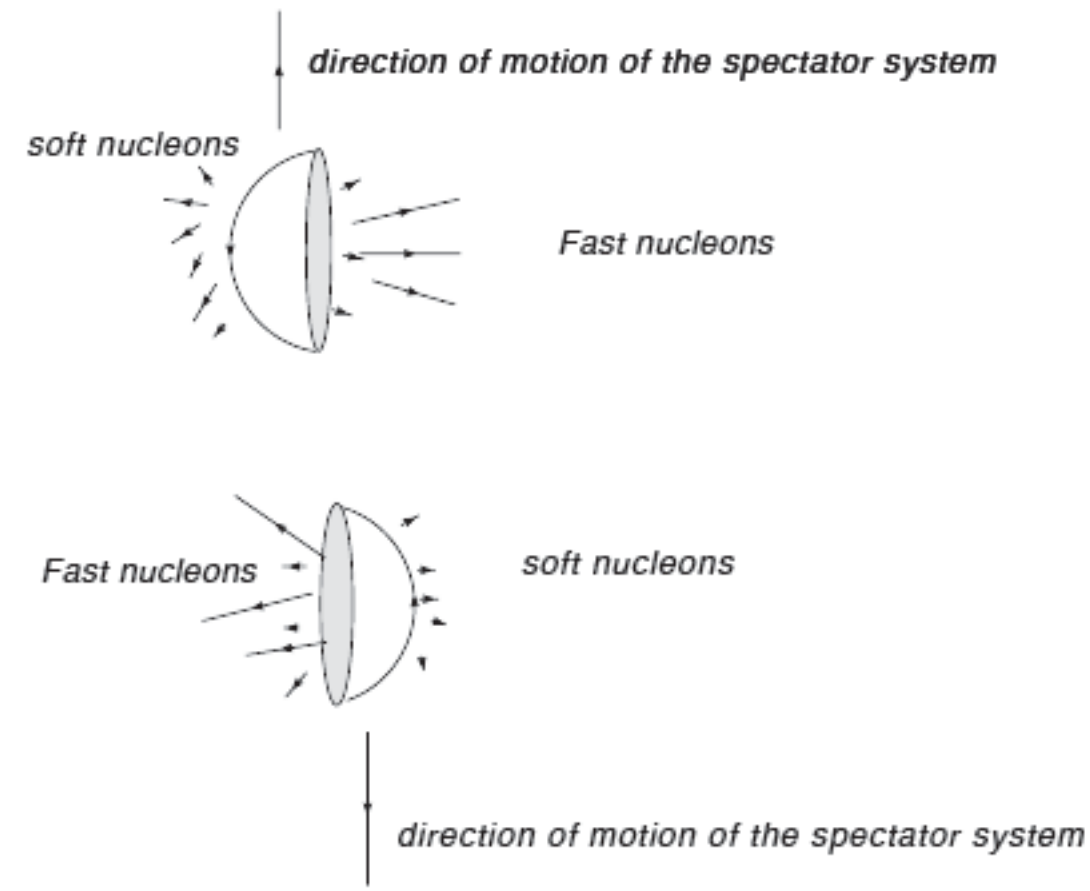
forward neutrons measure:
-impact parameter
-reaction plane (from directed flow, v_1)



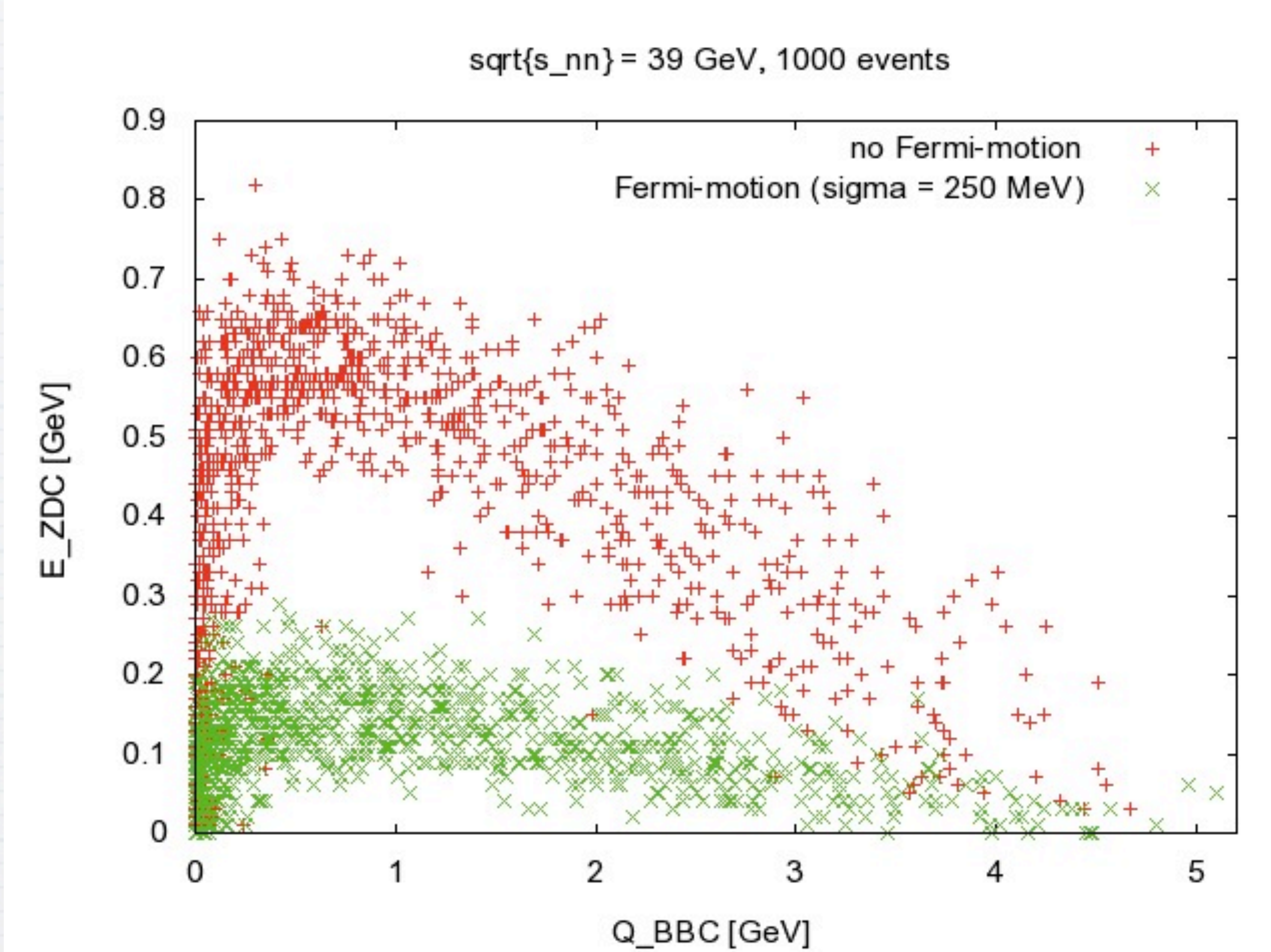
Surprisingly, significant aspects of this picture not modeled in HIJING !
- ie in HIJING, Fermi motion=0 !
-> new collaboration to include modeling of baryon "spectators"- Alvioli, Csorgo, Strikman, Vargyas, SNW

Csorgo. Strikman. SNW



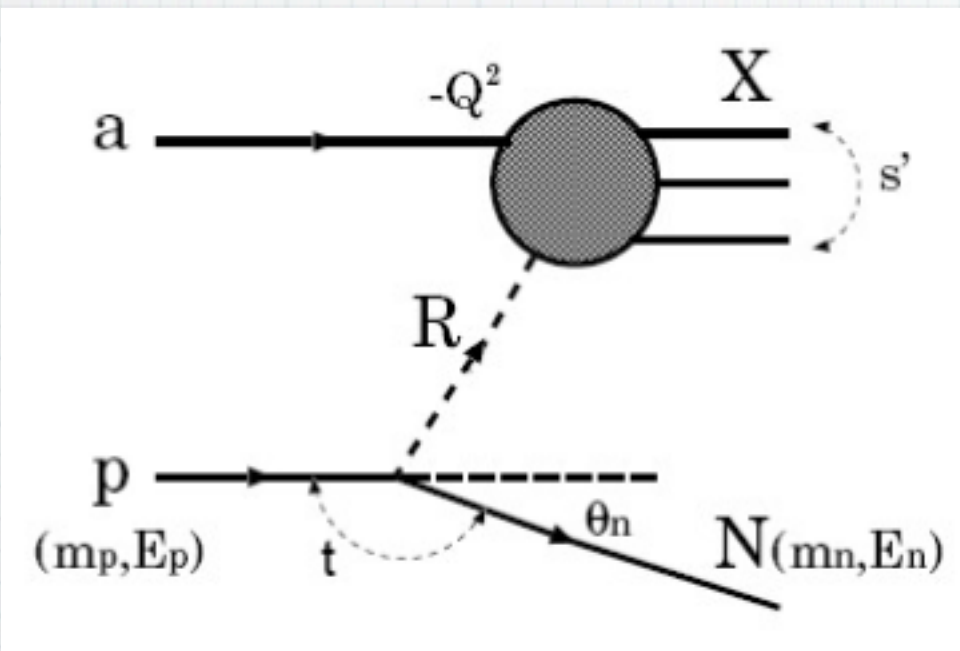


[0910.3205] Beam **Fragmentation** in Heavy Ion Collisions and its ...
Title: Beam **Fragmentation** in Heavy Ion Collisions and its implication for RHIC triggers at low s. Authors: Sebastian **White**, Mark **Strikman** ...
arxiv.org/abs/0910.3205 - Cached
by S White - 2009 - Related articles - All 4 versions

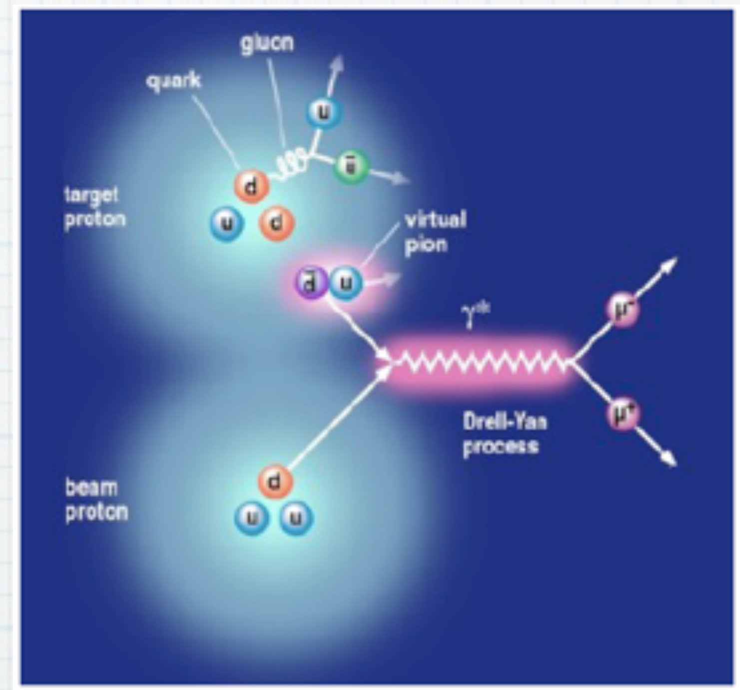

sqrt{s_nn} = 39 GeV, 1000 events
no Fermi-motion
Fermi-motion (sigma = 250 MeV)
E_ZDC [GeV]
Q_BBC [GeV]
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5

Neutron Production in pp

* most people have the following picture



ie->



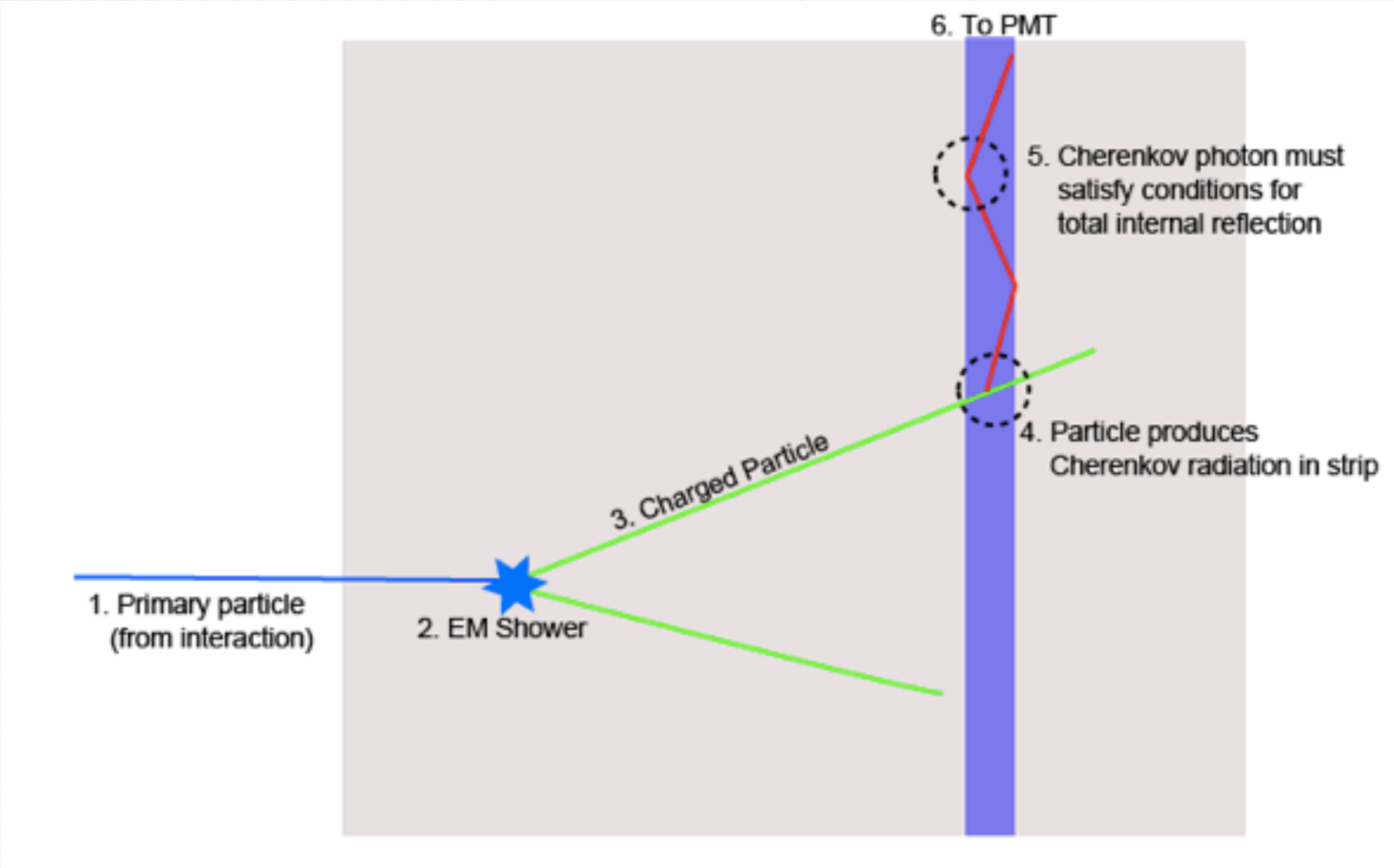
in RAPGAP "replace the Pomeron by pi+"

* Phenomonology of Inclusive neutron production from ISR, FNAL, HERA, RHIC
* coincident 2 neutron only from PHENIX
* ->modeling of LHC cross sections "Neutron Production and Zero Degree Calorimeter Acceptance at LHC"–SNW– arXiv:0912.4320v2 [hep-ph] In this model of non-diffractive +diffractive:
    * always a forward baryon, w. x_F & p_t given by HERA
    * 45% of these baryons are neutrons
    * to calculate 2 arm coincidence assume left-right distributions are uncorrelated. early comparison with this model by ATLAS (blessed in June):

Trigger type	ZDC-A_and_ZDC-C	ZDC-A_inclusive
σ(Effective) mbarn	4.4 +/- 0.6	17.6 +/- 1.3

Asymmetries

* Heavy Ions: Interest in sensitivity to reaction plane from v_1 led to position sensitive Shower Maximum Detector for the ZDC (Denisov & SNW)

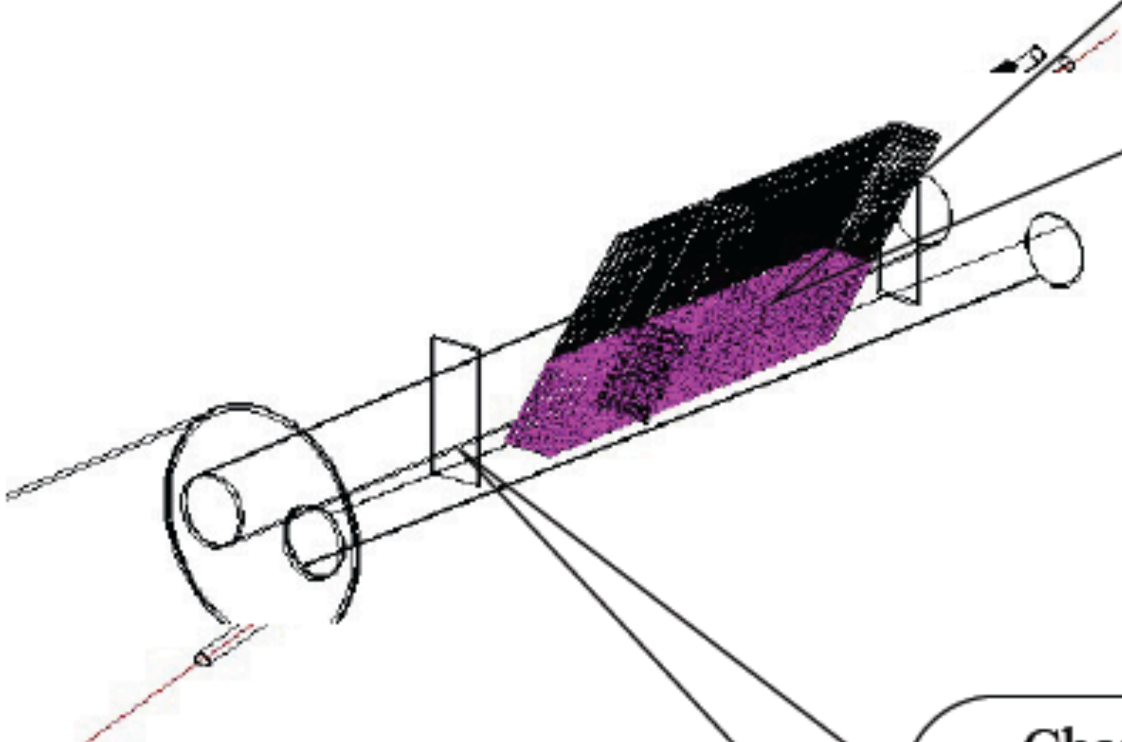


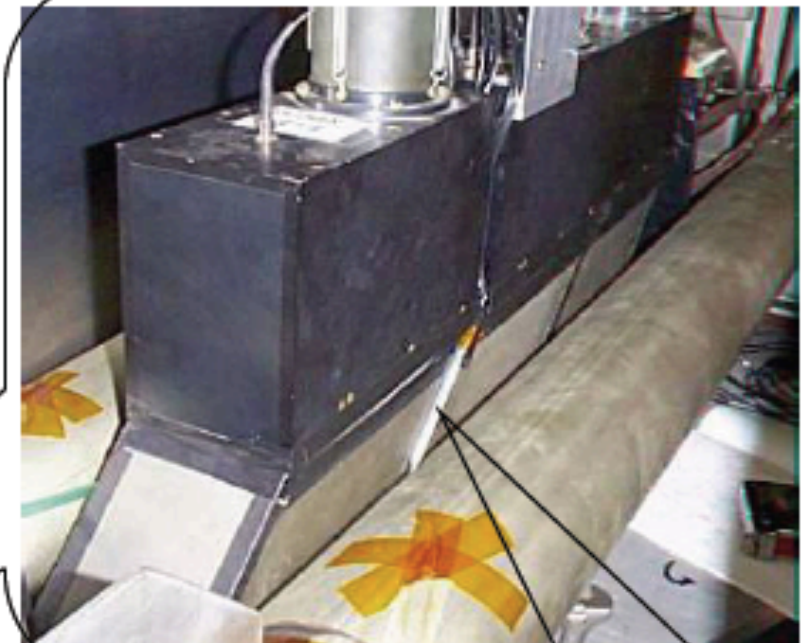
ZDC is based on Cerenkov sampling in optical fibers.
-very fast
-unusual response profile
-ATLAS uses quartz glass (5 GigaRad/year)

Setup

Schematic view from simulation.

- GEANT3 (Geisha)
- From the pythia simulation, Main backgrounds are photon and proton.



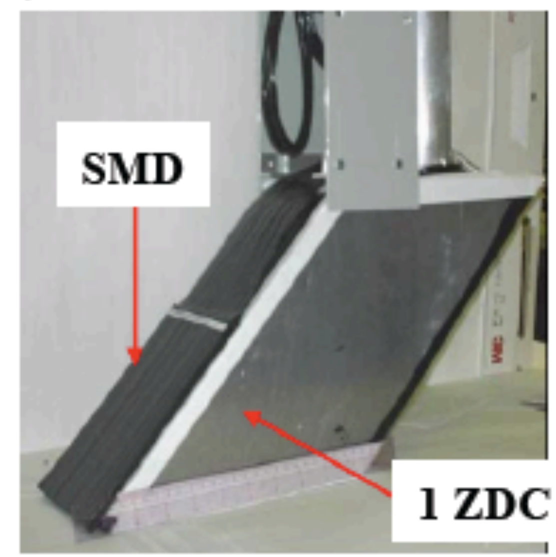


ZDC
(**Z**ero **D**egree **C**alorimeter)

10*10cm
→ ±2.8 mrad

3 module
$150X_0$ $5.1\lambda_I$

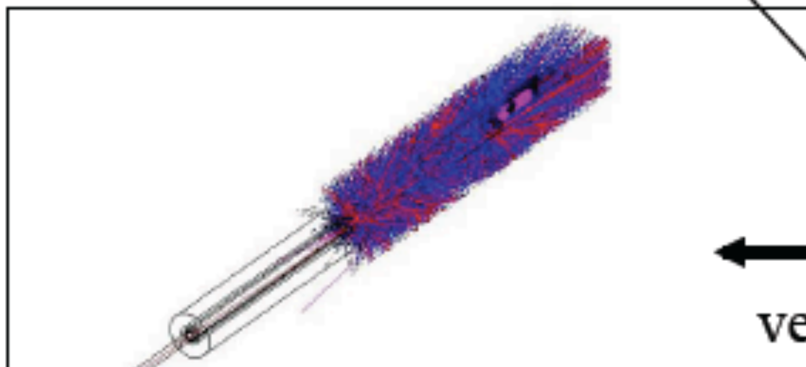
SMD
(**S**hower **M**ax **D**etector)



Neutron position can be found using centroid method (+/- 1cm).

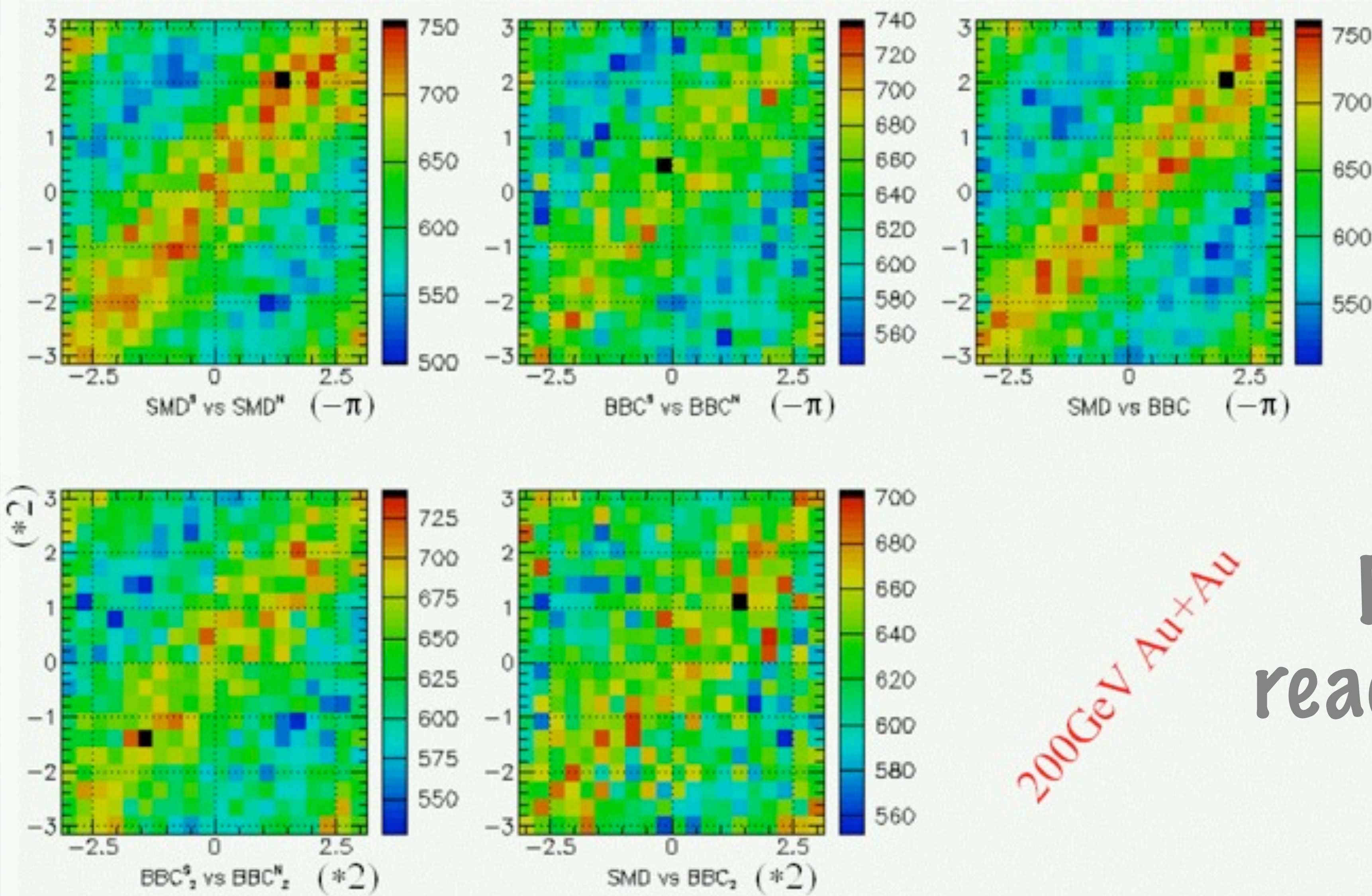
Charge veto counter

veto



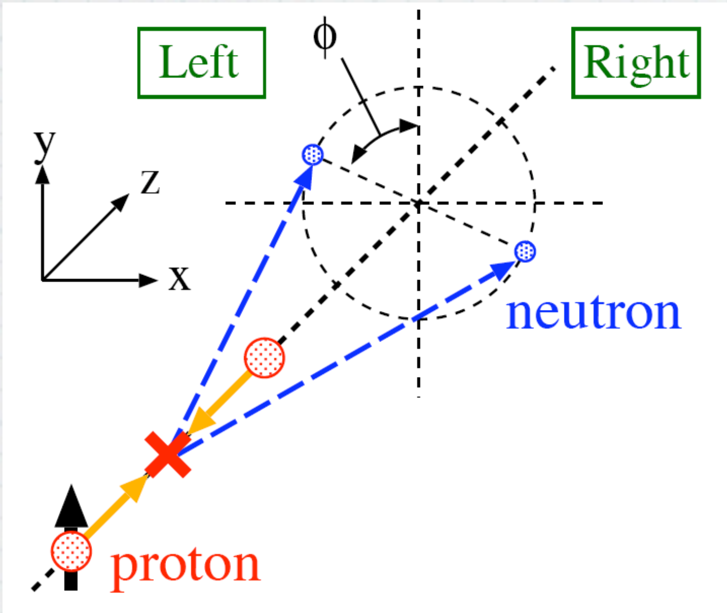
Proton shower event
(In case of proton mom. = 50GeV/c)

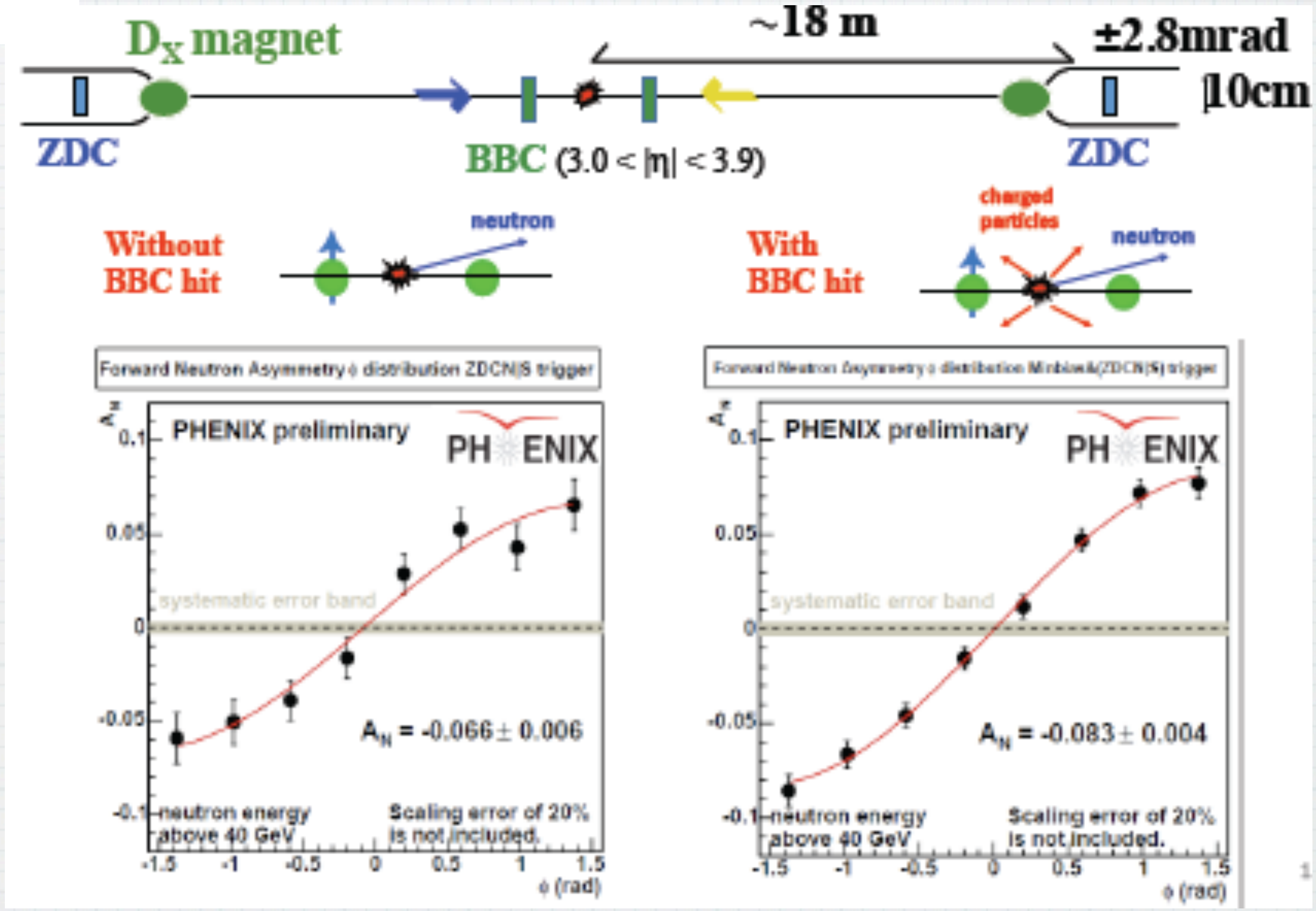
PHENIX analysis of reaction plane resolution



	Au+Au 200GeV	Au+Au 62GeV	
	$y_{beam}^{(100GeV)}=5.3$	$y_{beam}^{(31GeV)}=4.5$	$(3<\eta_{bbc}<4)$
$N_{ch}^{max}(bbc)$	~1600	~600	(multiplicity)
$v_1(bbc)$	1~2%	2~4%	(signal)
$v_2(bbc)$	2~2.5%	1.5~2%	(signal)
$\langle\cos\Delta\Phi_1^{BBC}\rangle$	4~5%	4~5%	(resolution)
$\langle\cos 2\Delta\Phi_2^{BBC}\rangle$	8~9%	2~3%	(resolution)
$\langle\cos\Delta\Phi_1^{SMD}\rangle$	7~8%	1~2%	(resolution)

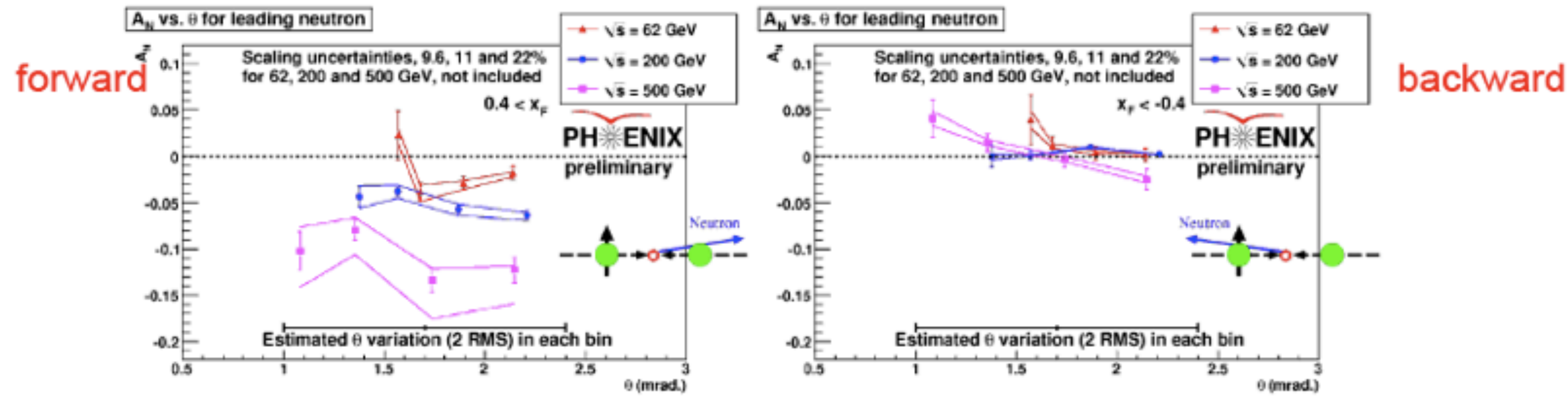
Spin dependent asymmetries in pp



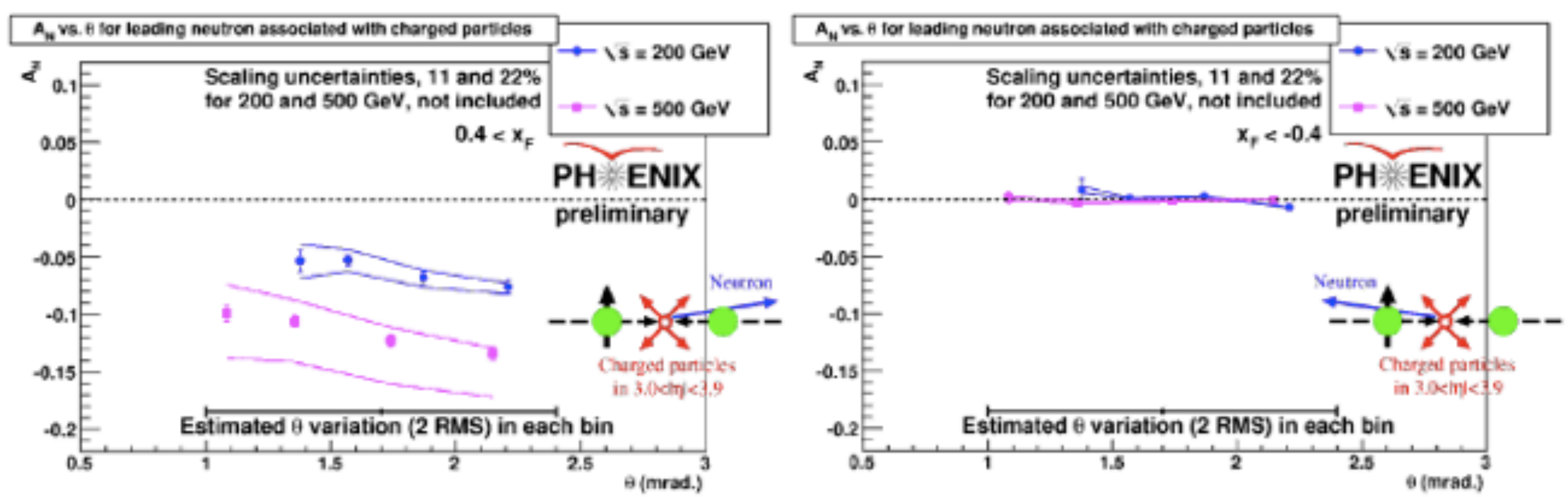


New results on s-dependence

– Inclusive neutron

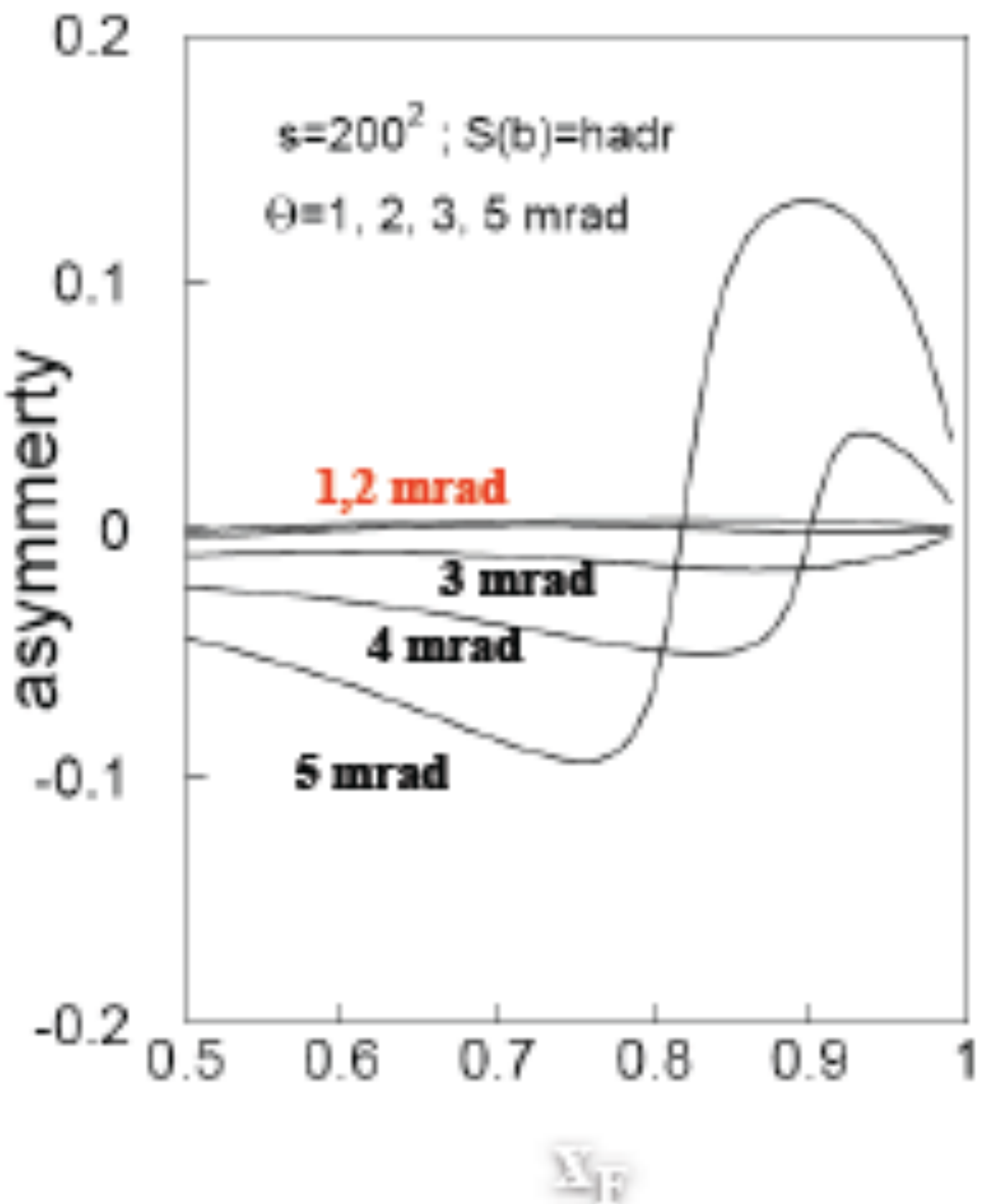


– Neutron with charged particles



Compare to calculated Asymmetry

B.Z. Kopeliovich, I.K. Potashnikov, I. Schmidt and J.Soffer
arXiv:0807.1449



- Asymmetry calculated with one pion exchange model.
- calculated asymmetry is smaller than observed.
  - PHENIX kinematic region :

    x_F=0.6-0.8, and θ < 2 mrad.
  - possibly due to other reggeon exchanges. (*e.g.* a_1 exchange)
  - testable with neutron p_t dist.

$$\frac{d\sigma}{dp_t^2}\vec{?}\rightarrow\frac{1}{(p_t^2+m_\pi^2)^2}$$

$$\texttt{OPE[pt\_]} := \frac{3.842\times 10^{-4}}{\left(pt^2 + m_\pi{}^2\right)^2}$$

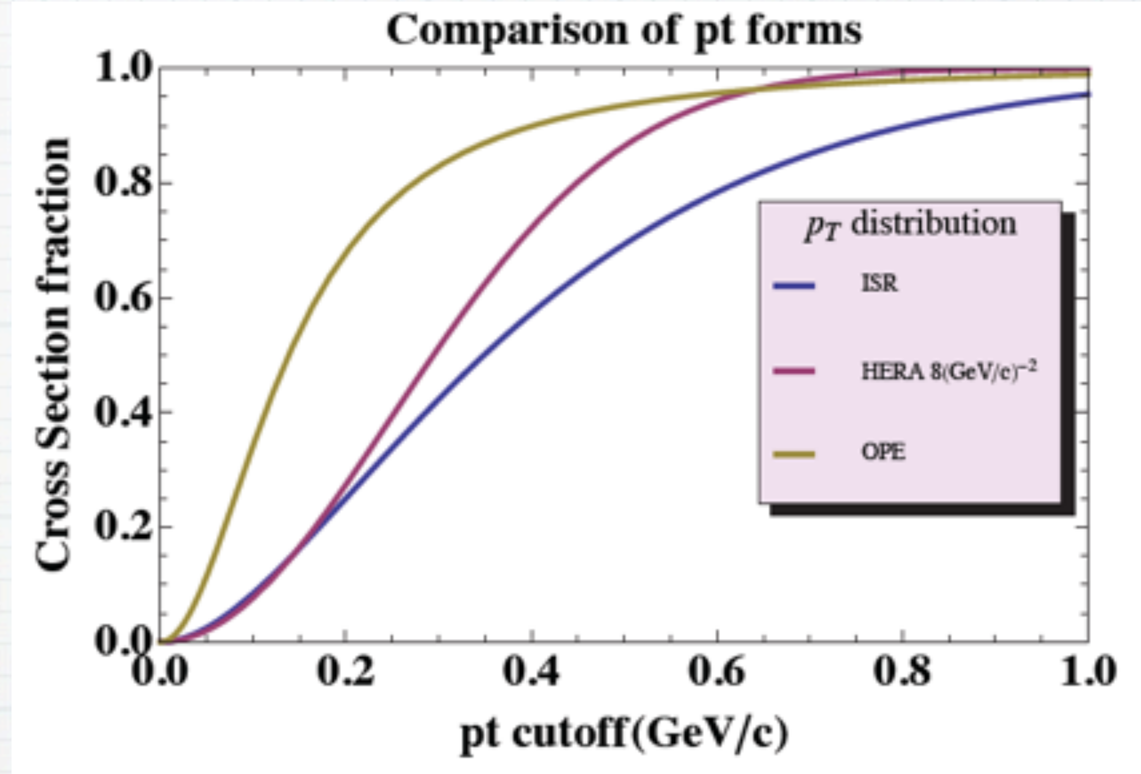
$$\texttt{OPEInt[y\_]} = \int_0^y pt\,\frac{.0393}{\left(pt^2 + m_\pi{}^2\right)^2}\,dpt;$$

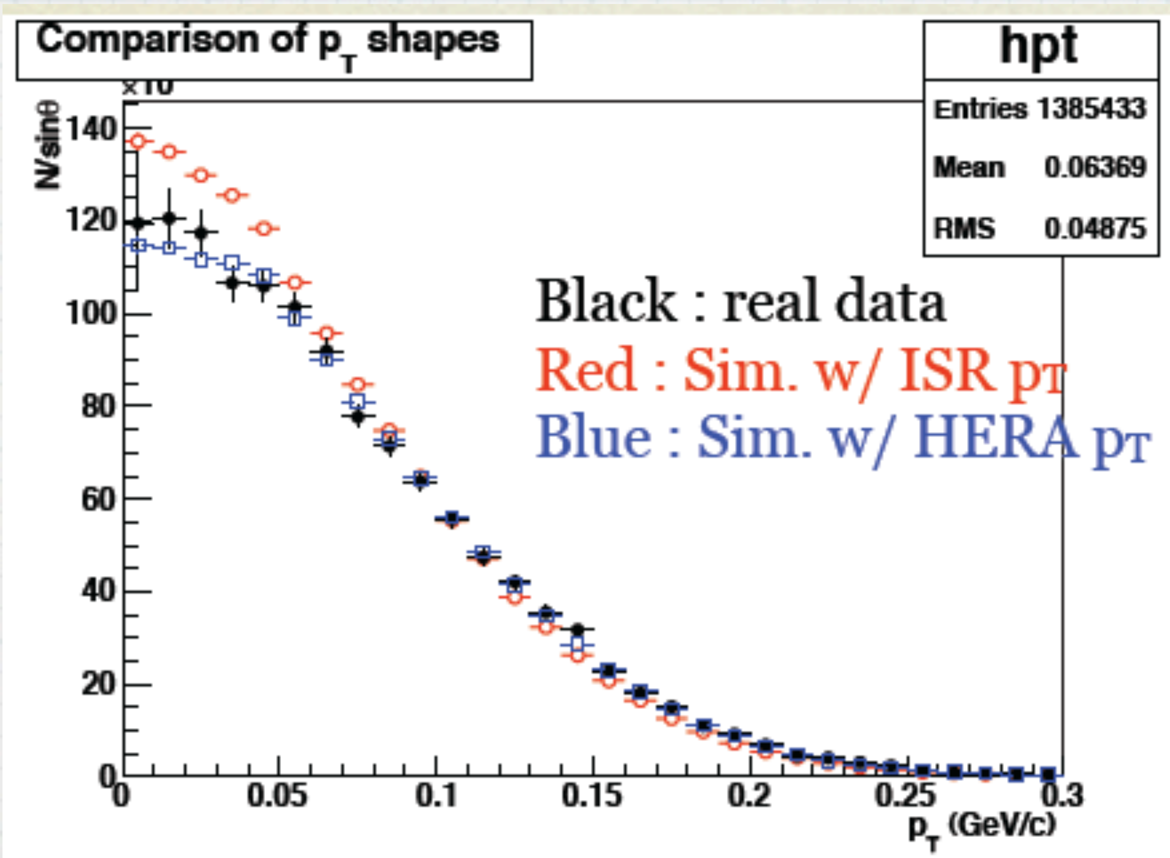
$$\texttt{ISR[pt\_]} := e^{-4.8\,pt}$$

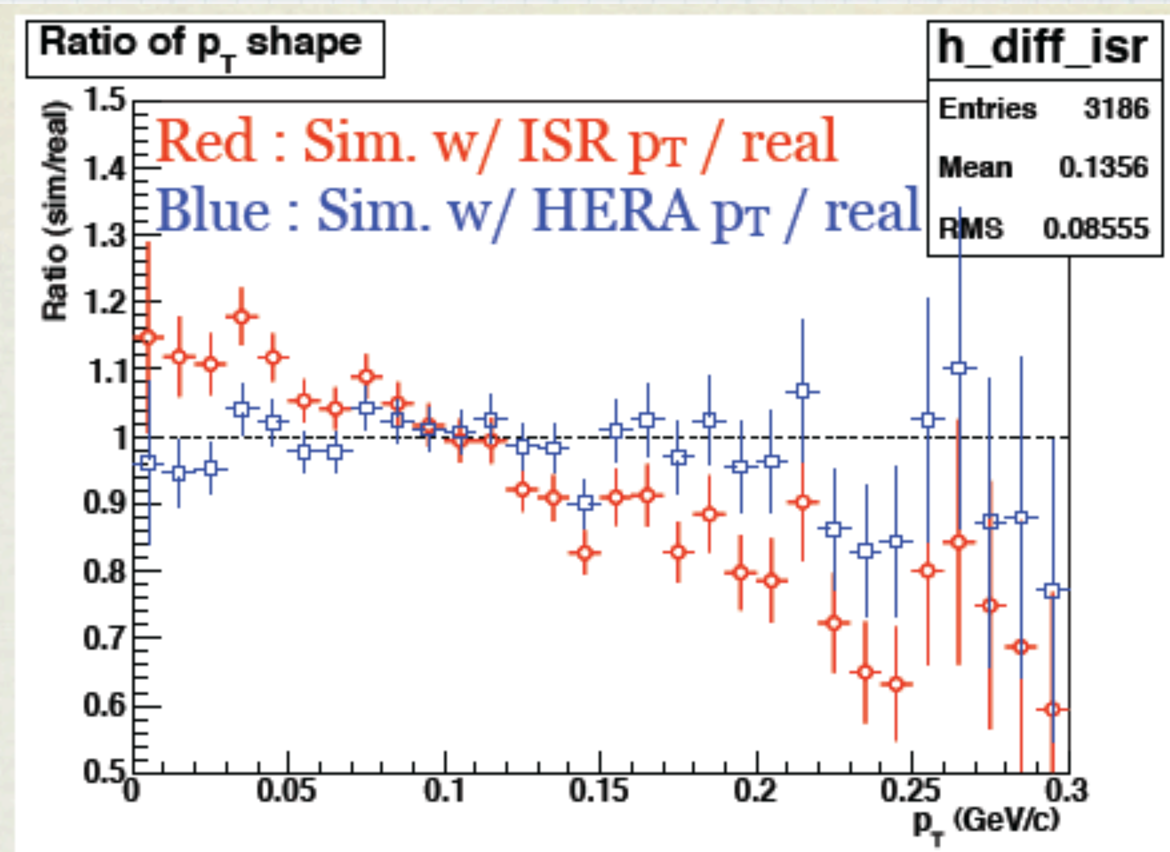
$$\texttt{ISRInt[y\_]} = 23.1\int_0^y pt\,\texttt{ISR[pt]}\,dpt;$$

$$\texttt{HERA[pt\_]} := e^{-8*pt^2}$$

$$\texttt{HERAInt[y\_]} = 16\int_0^y pt\,\texttt{HERA[pt]}\,dpt;$$







Conclusions

* see talk on Wednesday